IMAGE ANALYSIS FOR THE ROBOTIC EXPLORATION OF MARS. A. B. Ivanov, J. J. Lorre, J. M. Maki, [1]168-514 Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109-8099

Introduction.

Planetary exploration has relied on images for information exchange since its beginning. Even as non-image instruments, such as laser altimeters, infrared spectrometers, etc., are actively used, visual data contains valuable information and relatively easy to acquire. Additionally, images serve multiple purposes, including navigational usage, public outreach and education.

Over the years the Multimission Image Processing Laboratory (MIPL) at the Jet Propulsion Laboratory has supported virtually all imaging instruments flown in space (Voyagers, Viking Orbiters and Landers, Mars Pathfinder and many others). MIPL possesses unique experience and capabilities for image analysis. In this presentation we will outline some of the functions that are implemented operationally or being developed for upcoming missions. We put the emphasis on functions related to the operations and science data analysis of the lander missions - rover navigation, image mosaic generation, stereo image processing and true color enhancement. Some of these functions are also applicable for analysis of the orbiter imagery. The software described in this presentation is developed within the VICAR software suite. This will permit us to inherit many routines developed for the Mars Pathfinder and Mars 98 missions.

Rover Navigation.

When a rover traverses unfamiliar ground it becomes necessary to redetermine it's position and orientation. Software has been developed to perform this task. It accepts stereo pairs from any platform, including the rover itself, to solve for up to six variables. These variables are the rover location and it's heading, pitch, and roll. The software consists of two modules. Module 1 collects ranged way points chosen by an operator from any available stereo imagery and which flag prominent terrain likely to be seen later on. Module 2 projects the way point catalogue into rover stereo images taken from unknown locations. An operator moves recognized way points to their correct corresponding terrain features. After sufficient points are acquired a rover solution is performed. That solution permits the present rover images to be used to acquire additional way points, establishing an extended reference frame. This software can also be used for autonomous rover navigation, without reference to a "mother ship".

Mosaic Generation.

The current trend in camera design is to obtain many images with a small field of view and to later mosaic them. Software was developed to support this task for Mars Pathfinder, and subsequently is available for other projects. It consists of two modules. Module 1 solves for the actual camera pointing geometry given the estimated (or commanded) pointing. Most cameras do not point well enough to permit seamless mosaics to be generated. The solution is found by collecting tiepoints from all overlapping image pairs and solving for the true pointing globally. Module 2 projects each pixel onto a mosaic surface. The surface could be a physical image plane, a cylindrical rotating surface, or a field defined angularly such as by azimuth and elevation. Stereo mosaics can be constrained to epipolar geometry and can be in true color. The software can combine imagery from any set of different cameras at different times and locations, including orbital imagery.

Topography Generation.

Surface topography can be extracted from stereo pairs and assembled into a single data set. Two correlators are available for processing simultaneous stereo pairs. These are

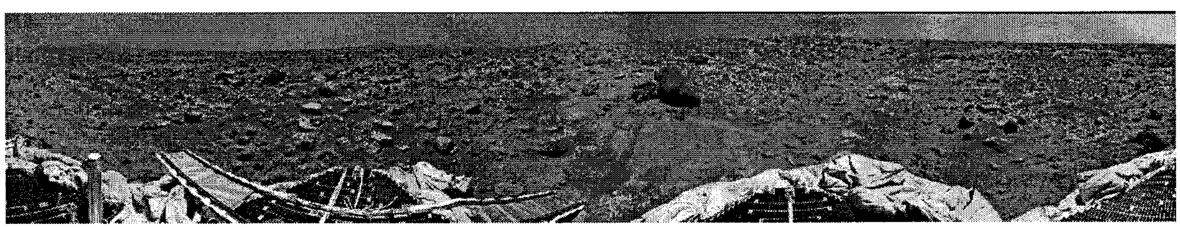

Figure 1. Geometrically improved, color enhanced version of the 360-degree 'Gallery Pan', the first contiguous, uniform panorama taken by the Imager for Mars (IMP) over the course of Sols 8, 9, and 10. Different regions were imaged at different times over the three Martian days to acquire consistent lighting and shadow conditions for all areas of the panorama. In this version of the panorama, much of the discontinuity that was due to parallax has been corrected, particularly along the lower tiers of the mosaic containing the Lander features. Distortion due to a 2.5 degree tilt in the IMP camera mast has been removed. This mosaic was produced at MIPL. This image illustrates mosaicing and color enhancement capabilities of MIPL.

two dimensional Gruen correlators which are unconstrained and one dimensional correlators which are constrained to epipolar lines and which operate upon distortion free images. Some versions of this software are able to extract topography from images obtained from unrelated instruments such as orbiters, descent cameras, and rovers.

True Color and Color Enhancement.

Most cameras are able to return multispectral imagery. Software exists to convert radiances into tristimulus values and from the tristimulus values into r,g,b true colors for several calibrated devices such as HDTV, film, and printers. In addition to true color the software permits color enhancements such as saturation exaggeration, and redefining gray, while constraining hue. This capability is important for both public consumption and for discriminating surface mineralogy when the scene is all one apparent color such as on Mars. A description of the color processing techniques can be found in [2].

Integration for rover operations and science analysis.

The above software modules generate rover pointing and retrieve topography from lander and orbiter cameras. This information can be integrated together and consequently used for rover operations using the approach described by Wright et. al. [1]. The authors describe how they can use topography and imagery together, and present information graphically to the rover operators and scientists. The necessary software is also developed in MIPL, so all the pieces can easily be assembled in one place. The described tools are extremely important for investigations in in-situ planetary geology and mission support for other instruments.

References.

[1] Wright, J. et al. , 2000, Integrated landing site characterization, ibid.

[2] Maki, J. N, et al., 1999, The color of Mars : Spectrophotometric measurements at the Pathfinder landing site, JGR, 104(E4), 8781-8794